Identification of Importance Criteria for Evaluating Suppliers' Performance During the Trial Production Stage: Case Study in Automotive Manufacturer

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Abstract

The major challenge for automotive manufacturers is to customize collaboration with vast supplier networks under uncertain conditions, such as unsatisfied quality, delivery shortage, and expensive costs during New Product Development (NPD). To address this concern, identifying appropriate criteria is a primary step for defining the best supplier performance for new model car development. Previous research has contributed to several criteria for performance evaluation with rating methods, but most focused on the mass production stage. However, few studies had done during the trial production stage. To bridge this gap, this study provides important criteria for Evaluating Supplier Performance (ESP) during the trial production stage by applying the Multi-Criteria Decision Making (MCDM) approach through the case study of a famous automaker in Thailand. The eighteen criteria were developed from an intensive literature review and thirteen experts survey. Then Consistent Fuzzy Preference Relationship (CFPR) approach is adopted to derive the relative importance weight of criteria through four perspectives; Quality Performance, Delivery Capability, Cost Compatibility, and Management Support. The objectives of this study provide appropriate criteria and prioritize the important criteria for ESP during the trial production stage, which helps to improve automaker-supplier collaboration in the automotive supply chain.

Keywords
New Product Development (NPD), Trial Production Stage, Evaluating Suppliers' Performance (ESP), Multi-Criteria Decision Making (MCDM), Consistent Fuzzy Preference Relationship (CFPR)

1. Introduction
The automotive industry is widely acknowledged as one of the enormous supply chains that need high collaboration between automakers and their supplier networks to enhance competitive advantage. As a result of global competition, automakers face the highest customer expectations and a race against time to deliver high quality at competitive prices, especially in sustainability trends, such as environmental policies and social concerns. In terms of New Product Development (NPD), increasing product complexity accelerates technological innovation, and unpredictability in customer demands pressure automakers to produce new products faster and more efficiently and launch them into the market on time (Sumrit 2020). Most organizations place high importance on NPD. The automaker cannot completely design a spare part on their own. For the new model car, many spare parts are supported by supplier networks, depending on the part complexity and development strategy. The main goal of supplier development is to assist suppliers in improving capabilities to meet project requirements. Each project has unique success variables requiring different approaches (Um and Kim 2019). Price, quality, delivery, and service are frequently used as performance indicators in supplier evaluation (Zheng et al. 2022). As a result, we require a technique and criteria that can be customized to each situation. The comparison of a practical condition between the trial production and mass production stages from four popular performance perspectives: quality, delivery, cost, and management, as shown in Table 1. The significant differences are the trial production stage required project flexibility of cross-functional team collaboration to manage and adjust conditions. (Vanichchinchai 2021a) reported that supplier collaboration is critical for supply chain performance in Thai manufacturing industry. On the other hand, mass production requires process monitoring and a responsive team to monitor production stability.

Table **1.** Comparison of a practical condition between trial production stage and mass production stage

Perspectives	**Trial production stage**	**Mass production stage**
Quality	- Process variation with high defect - Part accuracy on acceptable target - Unpredictable trouble	- Process standardization with low defect - Part accuracy 100**%** on Drawing - Predictable trouble
Delivery	- Small lot production; low inventory stock - Short lead time order - Adjustable time and various delivery locations - Engineering change capability	- Big lot production; high inventory stock - Long term forecast with the order confirmation - Just in time delivery with location fix - Production capacity
Cost	- Special cost; flexible price - High logistics cost - Investment cost; process, tooling, machine	- Commitment cost; fix price - Low logistics cost - Market claim cost
Management	- Master development plan - Frequent communication and information sharing - Agile cross-functional team	- Production plan - Alert and recovery management - Responsive production team

Nevertheless, performance evaluation is complex due to the inclusion of multiple criteria especially during unsteady period like the trial production stage. So, identifying appropriate criteria is the most priority needed to define before Evaluating Supplier Performance (ESP). The goals of the trial production stage are to simulate and optimize production conditions to ensure that new automotive parts can be developed efficiently and on time during the project development period (Schoenherr and Wagner 2016). Because a poor supplier performance during the trial production stage can cause trouble in the mass production stage, such as a market claim, production shortage and delay in delivering a new model car to the customer. However, most ESP studies focus on the mass production stage (Min et al. 2018) rather than the trial production stage.

To fill in the gap, this study aims to identify NPD criteria using the MCDM approach was demonstrated through a case study of a famous automaker in Thailand. Based on an intensive literature review, the CFPR approach was applied to prioritize the importance weight of eighteen criteria from four perspectives: quality performance, Delivery Capability, Cost Compatibility, and Management Support.

The aims of this study were provided with the two following objectives during the trial production stage as follows:

- To identify appropriate criteria for supplier performance evaluation during the trial production stage
- To prioritize the importance criteria through the MCDM approach

This study's contribution includes managerial practices for automakers to prioritize development activities and manage project schedules based on appropriate criteria during the trial production stage. Another advantage can improve automaker-supplier collaboration in the automotive supply chain.

2. Literature Review

2.1 New Product Development

In the automotive industry, automakers are not only selecting suppliers and adding them to a list, but they are also developing supplier performance to align with the new model car development plan. Suppliers and automakers can also work together to share resources, information, investments, and knowledge (Benton et al. 2020). Previous research has indicated that the involvement of an integrated NPD team and manufacturing team has a significant impact on NPD performance (Nafisia et al. 2016). Automakers frequently form a developer team to collaborate and evaluate suppliers throughout the development project's lifecycle (Kumara and Rahman 2015); training, workshop, technology sharing and process audit are provided to improve supplier performance (Benton et al. 2020). Thus, the NPD's effectiveness depends on the performance of suppliers involved in new model car development.
Generally, a new model car development can be divided into three stages, as shown in Table 2. The first stage was called the design stage. Designers team is in charge of designing concept cars and releasing drawings with

specifications. In this stage, a feasibility assessment is available for business selection. The second stage was called the trial production stage. Spare parts were produced for trial fitting and confirmed functional testing by a cross-functional team of designers and engineers. It is challenging to standardize processes and fix production conditions at this stage. Because the drawing with specifications of each single part is frequently adjusted after the functional test in the car does not meet the requirements. Trial production performance evaluation is used to identify how adaptable the process is to standardize the best conditions for mass production. The final stage is known as mass production stage, which is the production team in charge of maintaining process stability and monitoring the production plan. In this stage, Customer Specific Requirements (CSR) evaluation is available based on IATF requirements.

Table 2. A real case study description of a new model car development stage

	Design stage	**Trial production stage**	**Mass production stage**
Who	Designer team	Designer and Engineering team	Production team
What	• Concept car • Drawing with specification	• Part Fitting/Functional Test • Process standardization	• Process stability • Production plan
How	Feasibility evaluation	Trial production performance evaluation	Customer Specific Requirements (CSR) evaluation

2.2 Supplier Evaluation

To ensure overall supply chain performance, automakers should closely monitor the performance of their suppliers throughout the NPD period. ESP is a crucial strategy for resolving complex problems using multi-criteria decision-making (Sumrit 2022). Despite the existence of IATF 16949, which provides global quality standards in the automotive industry in terms of quality standards, process stability control, and measurement systems. Nevertheless, automakers have numerous requirements and criteria for selecting the best suppliers to develop their products. Park et al. (2009) proposed explicit purchasing approaches from several perspectives, including quality, cost, delivery, capacity, technology, and collaboration in previous research. However, the most appropriate tool for managing change in NPD is Engineering Change Management (ECM) which helps to improve quality, reduce costs, and maintain a strong market position against competitors by reducing time to market (Shivankar and Deivanathan 2021).
Identifying appropriate criteria is the primary step for SPE; it's essential to keep looking for alternative suppliers and adding them to the pool; meanwhile, it's good to review existing suppliers and offer incentives and penalties based on the assessment results (Park et al. 2009). Buyers should leverage pressure from potential suppliers to increase market competitiveness through increased specific investments by the existing supplier.

2.3 A Multi-Criteria Decision Making

Decision making is an inescapable part of real life. Data is usually insufficient, incomplete, or inaccurate. Complicated decision- making problems require many criteria of varying importance, and people are almost incapable of determining the optimal decisions (Shekhovtsov and Sałabun 2020). MCDM techniques are frequently successful in leading decision makers to the best solution for a specific decision problem by eliminating inconsistency in project variable selection (Biscaia et al. 2021). The most commonly used MCDM approaches for evaluating and selecting suppliers generally involve fuzzy-based methods. The basic concepts of the Consistent Fuzzy Preference Relation (CFPR) are introduced in this research.

3. Method and data collection

The CFPR method was introduced by Herrera-Viedma and is an efficient approach with consistent results. This method allows decision-makers to provide alternatives with minimum judgment, but it also eliminates the need to check for consistency throughout the decision-making process (Park et al. 2019) and simplifies severity weighing (Alias et al. 2019). Furthermore, the CFPR questionnaire is relatively short and simple for respondents to complete, increasing the probability of obtaining responses (Lu et al. 2019). In this study CFPR steps are provided as follows.

Step 1: Establish a pairwise comparison matrix for each expert by using pairwise comparisons of criteria. The scale of relative importance weight ranging from 1 to 9 as shown in Table 3. The result is represented in Equation 1:

$$A^k = \begin{array}{c} \\ C_1 \\ C_2 \\ C_3 \\ \vdots \\ C_n \end{array} \begin{array}{c} \begin{array}{ccccc} C_1 & C_2 & C_3 & \cdots & C_n \end{array} \\ \begin{bmatrix} 1 & a_{12}^k & \times & \times & \times \\ \times & 1 & a_{23}^k & \times & \times \\ \times & \times & 1 & a_{34}^k & \times \\ \vdots & \vdots & \vdots & \ddots & a_{n-1n}^k \\ \times & \times & \times & \times & 1 \end{bmatrix} \end{array} \tag{1}$$

here $a_{ij} \cdot a_{ji} = 1, \forall i, j \in \{1,2,\dots,n\}$, $a_{ij} \in \left[\frac{1}{9}, 9\right]$, and a_{ij}^k represents a pairwise preference score between criterion $i \text{ and } j$

Step 2**:** Aggregate a pairwise comparison matrix using Equation 2**:**

$$\tilde{a}_{ij} = \frac{1}{k}\left(a_{ij}^1 + a_{ij}^2 + \cdots + a_{ij}^k\right) \tag{2}$$

Step 3**:** Construct the preference matrix by transforming all element values from $\tilde{a} \in [\frac{1}{9}, 9]$ to $P = (p_{ij})$ with $p_{ij} \in [0,1]$ as follows**:**

$$p_{ij} = g(a_{ij}) = \frac{1}{2}\left(1 + log_9 a_{ij}\right) \tag{3}$$

$$p_{ij} + p_{ji} = 1 \quad \forall i, j \in \{1,2,\dots,n\} \tag{4}$$

$$p_{ij} + p_{jk} + p_{ki} = \frac{3}{2} \quad \forall i, j, k = 1,2,\dots,n \tag{5}$$

$$p_{ij} + p_{jk} + p_{ki} = \frac{3}{2} \quad \forall i, j, k \tag{6}$$

$$p_{ij} + p_{jk} + p_{ki} = \frac{3}{2} \quad \forall i < j < k \tag{7}$$

$$p_{i(i+1)} + p_{(i+1)(i+2)} + \cdots + p_{(j-1)j} + p_{ji} = \frac{j-i+1}{2} \tag{8}$$

Step 4**:** Establish a preference matrix based on the results step 3 as follows**:**

$$P = \begin{array}{c} \\ F_1 \\ F_2 \\ F_3 \\ \vdots \\ F_n \end{array} \begin{array}{c} \begin{array}{ccccc} F_1 & F_2 & F_3 & \cdots & F_n \end{array} \\ \begin{bmatrix} 0.5 & p_{12}^k & \times & \times & \times \\ 1 - p_{12}^k & 0.5 & p_{23}^k & \times & \times \\ \times & 1 - p_{23}^k & 0.5 & p_{34}^k & \times \\ \vdots & \vdots & \vdots & \ddots & p_{n-1n}^k \\ \times & \times & \times & \times & 0.5 \end{bmatrix} \end{array} \tag{9}$$

Where Equation **(**10**)** is determined to convert the preference matrix from $[a, 1 + a]$ to $[0,1]$

$$f(p_{ij}^k) = \frac{p_{ij}^k + a}{1 + 2a} \tag{10}$$

Step 5**:** Normalized all elements in the preference matrix as follows**:**

$$g_{ij} = \frac{p_{ij}}{\sum_{i=1}^n p_{ij}} \tag{11}$$

Step 6**:** Compute the importance weight by Equation (12):

$$w_j^s = \frac{\sum_{j=1}^n g_{ij}}{\sum_{i=1}^n \sum_{j=1}^n g_{ij}} \tag{12}$$

Table 3. The scale of relative importance weight

Relative importance	Meaning
1	Equally importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme importance
2,4,6,8	Intermediate values between two adjacent judgments

Source: Alias et al. (2019)

The empirical study was applied in a real case study of a famous automaker in Thailand named Firm A, an international corporation with over two hundred first tier suppliers. The name of this firm has not been revealed for reasons of confidentiality. This study aims to contribute important criteria for ESP during the trial production stage. Automakers and suppliers can manage workload, focusing on the priority criteria that can help customize collaboration, which is essential for establishing and developing supply chain sustainability. To identify and derive the important weight of criteria, this section provided the research procedure is divided into three phases, as shown in Figure 1.

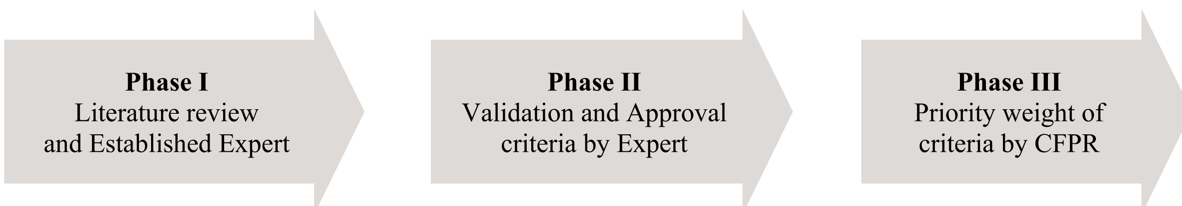

Figure 1. The research procedure

Phase I: Literature review and established Expert
Criteria for ESP during the trial production stage were identified through an intensive literature review which was developed from the mass production criteria. Then, the experts were established from the person who has at least fifteen years in the new model car development theme—consisting of thirteen qualified experts divided into two groups. The first group, "E1", is represented by six Thai section managers involved with new spare parts development, such as interior & exterior parts, body parts, chassis parts, and electronic parts. The second group, "E2", is represented by seven senior executive managers involved with the new car development strategy, including three Thai directors and four Japanese directors.

Phase II: Validation and Approval criteria by Expert
To correctly identify criteria in terms of new model car development. The experts E1. were in-depth interviewed to categorize a perspective and validate the criteria description from an intensive literature review. Then, the experts E2 were asked to approve those criteria to ensure that were appropriate for ESP during the trial production stage, as shown in Table 4.

Table 4. Perspectives and criteria for ESP during the trial production stage

Perspectives	Criteria	Description	Authors
Quality Performance (P1)	Part Quality (C1)	Defined as the rejection rate achievement with no concealed defects, during the trial production stage	Dweiri et al. (2016), Giannakis et al. (2020), Khan et al. (2018), Zhao and Cao (2015)
	Quality Commitment (C2)	Defined as the part quality guarantee by the management team in during the trial production stage	Benton et al. (2020), Corsten et al. (2011), Ruiz and Ravindran (2018), Schoenherr and Wagner (2016)
	Knowledge Integration (C3)	Defined as co-design tooling and process development during the trial production stage	Kumara and Rahmanb (2015), Schoenherr and Wagner (2016), Sumrit (2020)
	Technical Support (C4)	Defined as the technician can fully help solve quality issues and change requirements during the trial production stage	Benton et al. (2020), Schoenherr and Wagner (2016), Zhao and Cao (2015)
	FMEA Activities (C5)	Defined as the capabilities to predict risk from function missing, product defects during the trial production stage	Sumrit (2020), Zhao and Cao (2015)
Delivery Capability (P2)	Delivery Reliability (C6)	Defined as the Just in time (JIT) delivery or the reasonable lead time development during the trial production stage	Corsten et al. (2011), Kannan (2018), Görener et al. (2017), Zhao and Cao (2015), Khan et al. (2018)
	Engineering Changes (C7)	Defined as the capabilities to deliver engineering changes during the trial production stage	Sumrit (2020)
	Part Certification (C8)	Defined as the compliance part with laws and regulations during the trial production stage	Poltronieri et al. (2019), Zhao and Cao (2015)
	Documentations (C9)	Defined as the correctly and completely provided Production Part Approval Process (PPAP) during the trial production stage.	Corsten et al. (2011), Görener et al. (2017)
	Warehousing Management (C10)	Defined as the reliable stock management system to prevent product mixing and manage holding stock during the trial production stage	Görener et al. (2017), Liou et al. (2019)
Cost Compatibility (P3)	Reliable Pricing (C11)	Defined as the reliable prices on spare parts with quotation during the trial production stage	Corsten et al. (2011), Görener et al. (2017)
	Flexible Pricing (C12)	Defined as the proposal for alternative services and discounts during the trial production stage	Görener et al. (2017), Dweiri et al. (2016)
	Cost Assistance (C13)	Defined as the suggestion to control customers' project development costs during the trial production stage	Corsten et al. (2011), Zhao and Cao (2015)

Perspectives	Criteria	Description	Authors
Management Support (P4)	Business Compatibility (C14)	Defined as the compatible culture and accordant policy to customers' requirements	Ruiz and Ravindran (2018), Dweiri et al. (2016), Um and Kim (2019), Schoenherr and Wagner (2016), Maestrini et al. (2018)
	Flexible Management (C15)	Defined as the ability to cope with project variability and flexibility to serve the requirements during the trial production stage	Um and Kim (2019), Delic and Eyers (2020), Khan et al. (2018), Maestrini et al. (2018), Yang et al. (2019)
	Information Sharing (C16)	Defined as the frequent cooperation, responsive to the request or customer complaints during the trial production stage	Benton et al. (2020), Corsten et al. (2011), Görener et al. (2017), Kumara and Rahmanb (2015), Schoenherr and Wagner (2016), Yang et al. (2019)
	Health and Safety (C17)	Defined as the safety workplace and health policy	Giannakis et al. (2020), Khan et al. (2018), Memari et al. (2019)
	Green Policy (C18)	Defined as the available environmental activities are concerned with emissions and waste	Poltronieri et al. (2019), Memari et al. (2019)

Phase III: Weight of perspective and criteria by CFPR

In this phase, CFPR was used to eliminate human vagueness, ambiguity, and uncertainty. The seven experts E2: were asked to analyze the relative importance weight of criteria using the scale of relative importance weight from Table 3. The results of an importance weight assessment for criteria are shown in Table 5. Then, the importance weight of criteria was calculated using the CFPR method, the results of Equation (12) as shown in Table 6.

Table 5. The results of the importance weight assessment for criteria by experts

E2.1			**E2.2**			**E2.3**			**E2.4**			**E2.5**			**E2.6**			**E2.7**			**Average**		
C1	6	C2	C1	1	C2	C1	3	C2	C1	6	C2	C1	1/3	C2	C1	1/7	C2	C1	4	C2	C1	2.925	C2
C2	1/6	C3	C2	1	C3	C2	2	C3	C2	1/5	C3	C2	1	C3	C2	1	C3	C2	8	C3	C2	1.910	C3
C3	1/7	C4	C3	1	C4	C3	1/3	C4	C3	3	C4	C3	1/3	C4	C3	1/5	C4	C3	1/3	C4	C3	0.763	C4
C4	1/7	C5	C4	1	C5	C4	4	C5	C4	1/5	C5	C4	1/3	C5	C4	1/4	C5	C4	1/6	C5	C4	0.870	C5
C5	5	C6	C5	5	C6	C5	1/6	C6	C5	5	C6	C5	3	C6	C5	6	C6	C5	7	C6	C5	4.452	C6
C6	3	C7	C6	1	C7	C6	4	C7	C6	1/6	C7	C6	1/3	C7	C6	1/5	C7	C6	1/4	C7	C6	1.279	C7
C7	1/8	C8	C7	1/9	C8	C7	1/5	C8	C7	1/6	C8	C7	1/4	C8	C7	1/4	C8	C7	5	C8	C7	0.872	C8
C8	7	C9	C8	9	C9	C8	3	C9	C8	8	C9	C8	4	C9	C8	6	C9	C8	3	C9	C8	5.714	C9
C9	1/8	C10	C9	7	C10	C9	2	C10	C9	1/7	C10	C9	1	C10	C9	1	C10	C9	6	C10	C9	2.467	C10

C10	7	C11	C10	1/5	C11	C10	1/4	C11	C10	4	C11	C10	3	C11	C10	1/3	C11	C10	3	C11	C10	2.540	C11
C11	5	C12	C11	5	C12	C11	3	C12	C11	4	C12	C11	2	C12	C11	1/3	C12	C11	7	C12	C11	3.762	C12
C12	1/5	C13	C12	1	C13	C12	3	C13	C12	1/4	C13	C12	1/2	C13	C12	1/5	C13	C12	1/8	C13	C12	0.754	C13
C13	1/7	C14	C13	1/5	C14	C13	1/2	C14	C13	1/5	C14	C13	1	C14	C13	1/4	C14	C13	1/8	C14	C13	0.345	C14
C14	4	C15	C14	1	C15	C14	1/2	C15	C14	3	C15	C14	1/3	C15	C14	3	C15	C14	1/5	C15	C14	1.719	C15
C15	1/7	C16	C15	1	C16	C15	4	C16	C15	1/6	C16	C15	3	C16	C15	1	C16	C15	1/7	C16	C15	1.350	C16
C16	1/7	C17	C16	1/7	C17	C16	2	C17	C16	1/5	C17	C16	1/4	C17	C16	1/5	C17	C16	7	C17	C16	1.419	C17
C17	3	C18	C17	1	C18	C17	1/2	C18	C17	7	C18	C17	3	C18	C17	1/5	C18	C17	3	C18	C17	2.529	C18

Table 6. The important weight of criteria by CFPR

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	g_{ij}	w_j^s	Ranking
C1	0.000	0.562	0.600	0.584	0.576	0.663	0.678	0.670	0.771	0.824	0.878	0.955	0.938	0.877	0.908	0.926	0.946	1.000	0.742	0.087	1
C2	0.438	0.000	0.538	0.522	0.514	0.601	0.615	0.607	0.709	0.761	0.815	0.892	0.876	0.814	0.846	0.863	0.884	0.938	0.680	0.080	2
C3	0.400	0.462	0.000	0.484	0.476	0.563	0.577	0.569	0.671	0.723	0.778	0.855	0.838	0.776	0.808	0.826	0.846	0.900	0.642	0.076	5
C4	0.416	0.478	0.516	0.000	0.492	0.579	0.593	0.585	0.687	0.739	0.793	0.871	0.854	0.792	0.824	0.841	0.862	0.916	0.658	0.077	4
C5	0.424	0.486	0.524	0.508	0.000	0.587	0.601	0.593	0.695	0.747	0.802	0.879	0.862	0.800	0.832	0.849	0.870	0.924	0.666	0.078	3
C6	0.337	0.399	0.437	0.421	0.413	0.000	0.514	0.506	0.608	0.660	0.715	0.792	0.775	0.713	0.745	0.762	0.783	0.837	0.579	0.068	6
C7	0.322	0.385	0.423	0.407	0.399	0.486	0.000	0.492	0.593	0.646	0.700	0.777	0.761	0.699	0.731	0.748	0.768	0.822	0.564	0.066	8
C8	0.330	0.393	0.431	0.415	0.407	0.494	0.508	0.000	0.601	0.654	0.708	0.785	0.769	0.707	0.739	0.756	0.776	0.830	0.572	0.067	7
C9	0.229	0.291	0.329	0.313	0.305	0.392	0.407	0.399	0.000	0.553	0.607	0.684	0.667	0.606	0.637	0.655	0.675	0.729	0.471	0.055	9
C10	0.176	0.239	0.277	0.261	0.253	0.340	0.354	0.346	0.447	0.000	0.554	0.631	0.615	0.553	0.585	0.602	0.622	0.676	0.418	0.049	10
C11	0.122	0.185	0.222	0.207	0.198	0.285	0.300	0.292	0.393	0.446	0.000	0.577	0.561	0.499	0.530	0.548	0.568	0.622	0.364	0.043	11
C12	0.045	0.108	0.145	0.129	0.121	0.208	0.223	0.215	0.316	0.369	0.423	0.000	0.484	0.422	0.453	0.471	0.491	0.545	0.287	0.034	17
C13	0.062	0.124	0.162	0.146	0.138	0.225	0.239	0.231	0.333	0.385	0.439	0.516	0.000	0.438	0.470	0.487	0.508	0.562	0.304	0.036	15
C14	0.123	0.186	0.224	0.208	0.200	0.287	0.301	0.293	0.394	0.447	0.501	0.578	0.562	0.000	0.532	0.549	0.569	0.623	0.365	0.043	11
C15	0.092	0.154	0.192	0.176	0.168	0.255	0.269	0.261	0.363	0.415	0.470	0.547	0.530	0.468	0.00	0.517	0.538	0.592	0.334	0.039	13
C16	0.074	0.137	0.174	0.159	0.151	0.238	0.252	0.244	0.345	0.398	0.452	0.529	0.513	0.451	0.483	0.000	0.520	0.574	0.316	0.037	14
C17	0.054	0.116	0.154	0.138	0.130	0.217	0.232	0.224	0.325	0.378	0.432	0.509	0.492	0.431	0.462	0.480	0.000	0.554	0.296	0.035	16
C18	0.000	0.062	0.100	0.084	0.076	0.163	0.178	0.170	0.271	0.324	0.378	0.455	0.438	0.377	0.408	0.426	0.446	0.000	0.242	0.028	18

4. Results and Discussion

This research provided the improvement of automotive supply chain collaboration by identifying appropriate criteria and prioritizing the importance weight of criteria during the trial production stage through the MCDM method that can contribute to the performance evaluation. The result from CFPR prioritizes the importance weight of eighteen criteria from four perspectives, as shown in Table 6. This study found that Part Quality (C1) has the highest relative importance weight of (0.087), followed by Quality Commitment (C2) of (0.080), and FMEA Activities (C5) of (0.078). All of the top three criteria with the highest relative importance weight are related to Quality Performance, which is the most influential perspective in supplier performance (Khan et al. 2018), corresponding with Zheng et al. (2022) mentioned that part quality is always an importance criterion in any manufacturing industry. Delivery Reliability (C6) of (0.068) is the most important criteria in Delivery Capability. Followed by Reliable Pricing (C11) and Business Compatibility (C14), which are the most equally important criteria of (0.043) in Cost Compatibility and Management Support, respectively.

These findings imply that the most important criteria during the trial production stage are Quality Performance and Delivery Capability. Automakers should prioritize part quality and delivery reliability to ensure production stability in the mass production stage, which leaves no room for error, corresponding with the ultimate goal of trial production established as the best practice before mass production. However, Cost Compatibility and Management Support are crucial as supported criteria for automakers which are the keys required to deal with project investment and other inevitable changes during the trial production stage.

5. Conclusion

With various requirements in the automotive supply chain and unpredictability during NPD. Automotive manufacturers are considering identifying good supplier performance during the trial production stage. This study presents the CFPR method for prioritizing appropriate criteria for ESP during the trial production stage through four perspectives, namely: Quality Performance, Delivery Capability, Cost Compatibility, and Management Support. Moreover, these findings provide practical implications for managerial collaboration with their suppliers during automakers' new model car development. Correspondingly, suppliers will have a guide to focus on the tangible criteria validated by an automaker.

To the best of the authors' knowledge, no prior automaker prioritized appropriate criteria in Thailand during the trial production stage. These findings are the primary step in ESP. Future research can contribute to other strategies of the automotive development cycle, such as supplier selection and supplier development, to find potential suppliers to customize development for segmentation and ranking suppliers' performance for any future business selection (Min et al. 2018). Moreover, future research can extend this preliminary methodology into other industries. The concept of priority nonconformity index (PNCI) proposed by (Vanichchinchai 2021b) may be applied to assess prioritization of supplier performance by comparing importance and performance criteria in future study.

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